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COUNTRY	Rumania	REPORT	
SUBJECT	Brochure by Rumanian People's Republic (1963) on Reclamation Developments in the Rumanian Peoples Republic	DATE DISTR.	20 Jun 63
		NO. PAGES	2
		REFERENCES	
DATE OF INFO.			
PLACE & DATE ACQ.			50X1-HUM

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THIS IS UNEVALUATED INFORMATION

1. 36 page pamphlet in English, on Reclamation Developments in the Rumanian People's Republic. It was published in 1963 by the National Committee on Irrigation and Drainage of the Rumanian People's Republic. UNCLASSIFIED

2. The brochure is made up of the following topics:

(A) Reclamation Developments in the Rumanian People's Republic

(B) The complex of Embankment, Drainage and Irrigation Works of the Borcea de Sus Reclamation System.

1 Embankment

2 Drainage Works

3 Developments for Irrigations

4 Conclusions on performed reclamation works

(C) The Mircea Voda (Carasu) - Irrigation System executed on Loess

3. The pamphlet shows 18 photographs of reclamation projects in Rumania.

4. The brochure contains the following drawings:

(A) Zones where reclamation works were executed in Rumania

1 The Borcea de Sus reclamation system

2 The Mircea Voda (Carasu) irrigation system

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STATE	ARMY	NAVY	AIR	FBI	AEC				

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(B) Embankment works of the subunit "Borcea de Sus" (compartimentation).

(C) Cross section through the belt embankment of Compartment One - Borcea de Sus.

(D) Complex of irrigation and drainage works - Borcea de Sus

(E) Geotechnical cross-section through compartment one - Borcea de Sus

(F) The Mircea Voda (Carasu) Irrigation System

(G) Infiltration of water under irrigation canals in a loessoid soil.

- end -

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(B) Embankment works of the subunit "Borcea de Sus" (compartimentation).

(C) Cross section through the belt embankment of Compartment One - Borcea de Sus.

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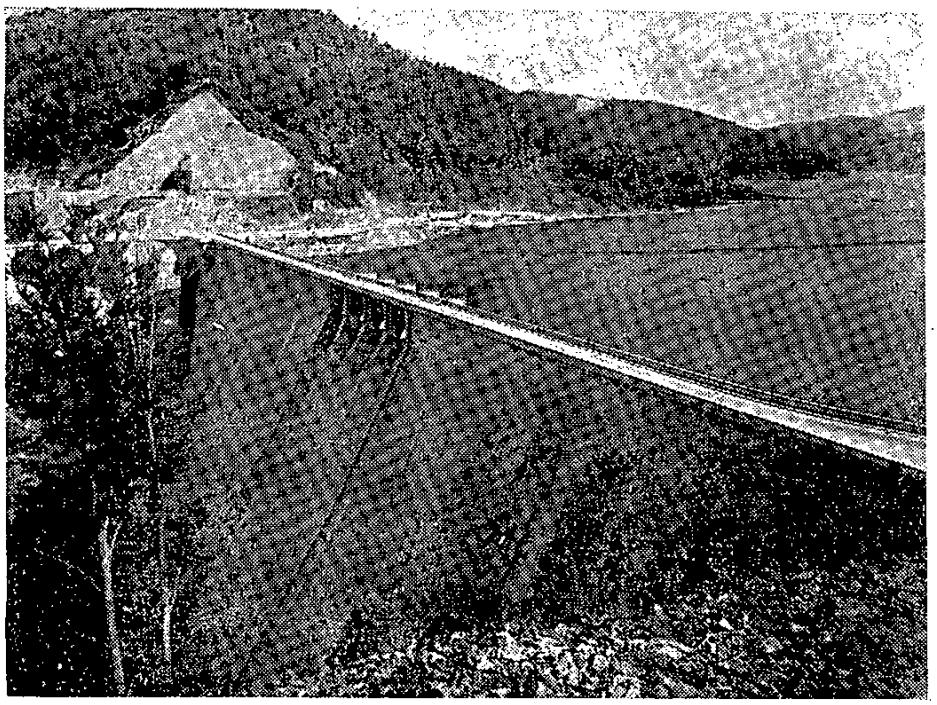
NATIONAL COMMITTEE ON IRRIGATION AND DRAINAGE
OF THE RUMANIAN PEOPLE'S REPUBLIC

RECLAMATION DEVELOPMENTS IN THE RUMANIAN PEOPLE'S REPUBLIC



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CONTENTS

	Page
Reclamation Developments in the Rumanian People's Republic	5
1. The Complex of Embankment, Drainage and Irrigation Works of the "Borcea de Sus" Reclamation System	14
2. The "Mircea Vodă" (Carasu) Irrigation System Executed on Loess	24

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RECLAMATION * DEVELOPMENTS IN THE RUMANIAN PEOPLE'S REPUBLIC

The Rumanian People's Republic lies in South-Eastern Europe, on the western shore of the Black Sea, between longitude 20°15′—29°41′ east and latitude 43°37′—48°15′ north. The 25° (east) meridian and 46° (north) parallel pass almost through the center of the country.

The area of the Rumanian People's Republic is 237,000 km² being located almost entirely in the basin of the Danube river which forms the southern border of the country. In the central part there is the mountainous massif of the Carpathians whose altitude ranges between 800—2,440 m and occupies 30 per cent of the total area. On both sides of the mountains there is a range of hills and tablelands with altitudes between 200—800 m occupying 27 per cent of the country's area, followed by vast plains with altitudes below 200 m, repesenting 33 per cent of the country's area (Fig. 1).

Owing to the geographical position and configuration, the climate varies, being subjected to the influence of three different climates : continental (Central European), excessive continental (East European) and maritime (under the influence of the Mediter-

* Reclamation is used in the present paper instead of "land drainage" including flood protection, ground water level control, water conservation and irrigation, in order to avoid confusion between "land drainage" and "field drainage".

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ranean and Black Sea). The annual average temperature varies between 10°—11°C in the plain zone, 7°—10° in the hill zone and below 6°C in the mountain zone (Fig. 1). The annual average

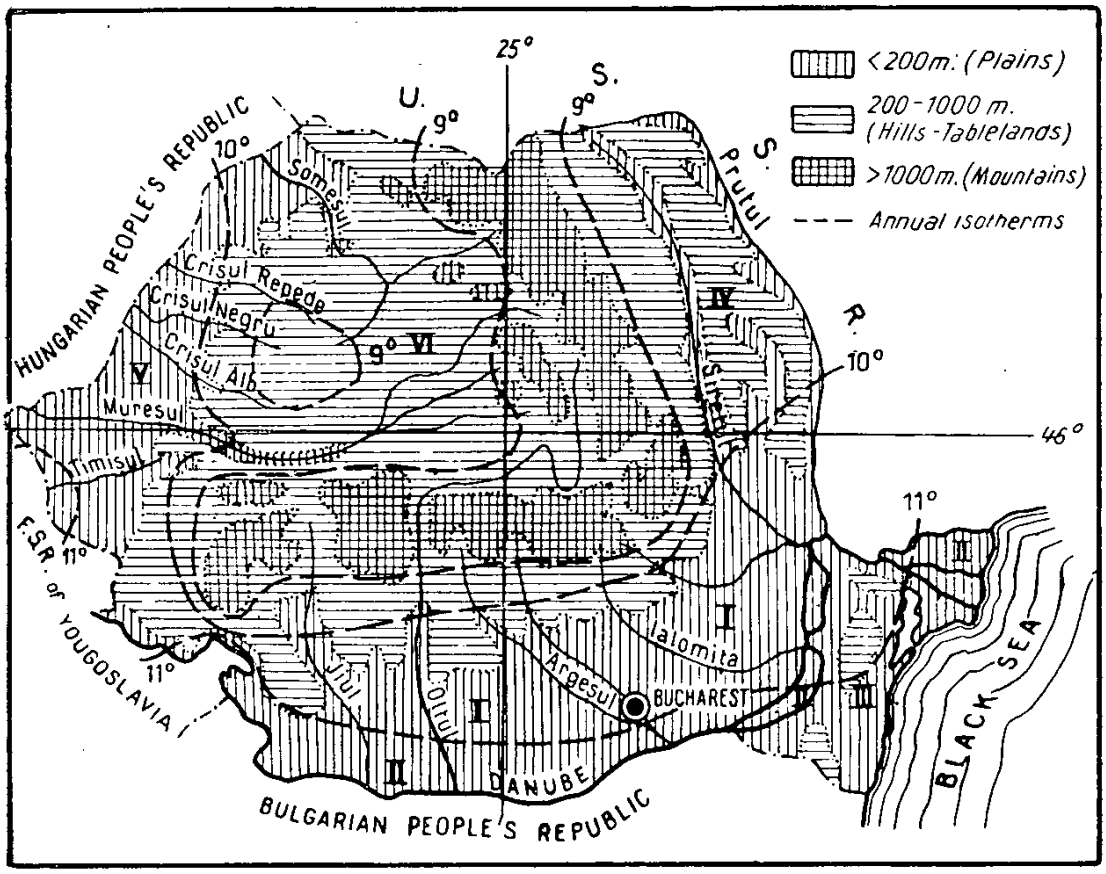

Fig. 1. Physic-geographic outline of the Rumanian People's Republic:
I—The Rumanian Plain; II—The Danube Flood Plain and Delta; III—The Dobrudgea; Tableland; IV — The Moldavian Tableland; V — The Western Plain (The Tisa Plain) VI — The Transylvanian Tableland.

precipitations vary between 350—600 mm in the plains, 600—800 mm in the hill area and 800—1,400 mm in the mountain area.

The hydrographic network belongs almost entirely to the Danube basin, flowing into the river either directly (the southern and eastern rivers of the country) or through the Tisa river (the western rivers). A small number of rivers flow directly into the Black Sea. The average density of the hydrographic network is 0.49 km/km².

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The agricultural area (14,545,000 ha) represents about 61 per cent of the total area of the country being mostly developed in the plain and hill-tableland regions.

Due to the climate, hydrologic, hydrogeologic and physical relief conditions which differ from one zone to another, various reclamation problems arise with regard to the agricultural lands of the Rumanian People's Republic of which we mention :

— control of floods produced by the periodical overflow of watercourses over an area of about 2.2 million ha;
— removal by drainage of the periodical excess of water in the soil or at its surface produced by the overflow of rivers, heavy rainfall on impermeable lowlands or high ground-water levels from an area of about 2.8 million ha which includes also the land situated in flood plains;
— completion of the periodic water deficit by irrigation in about 5 million hectares of farmland situated in arid zones in the south-east and in the west of the country;
— prevention and control of soil salinization in an area of about 300,000 ha in zones with a shallow water table and high content of salts.

Moreover, important problems are related to the prevention and control of soil erosion by adequate means of soil conservation in vast areas occupied by sloping ground.

For the development of a rational and intensive agriculture in the above mentioned areas, certain reclamation works have so far been carried out. The major part of these works were accomplished after 1944 under the people's democratic regime which pays particular attention to reclamation projects in order to create the conditions for the continuous development of our agriculture.

By the end of 1962 the following reclamation works were carried out :

— flood control in flood plains within an area of about 850,000 ha, representing nearly 40 per cent of the total

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floodable area which can be reclaimed by this kind of works;

— field drainage of farmlands of about 640,000 ha representing 23 per cent of the total area affected by periodical water excess;

— irrigation of about 220,000 ha representing 4.5 per cent of the total area of the land with a periodical water deficit.

Works for the prevention and control of soil erosion were also carried out in vast agricultural areas situated on the sloping terrains in the hill and tableland regions.

Fig. 2 shows the regions in which reclamation (embankments, drainage and irrigation) work was carried out up to the present

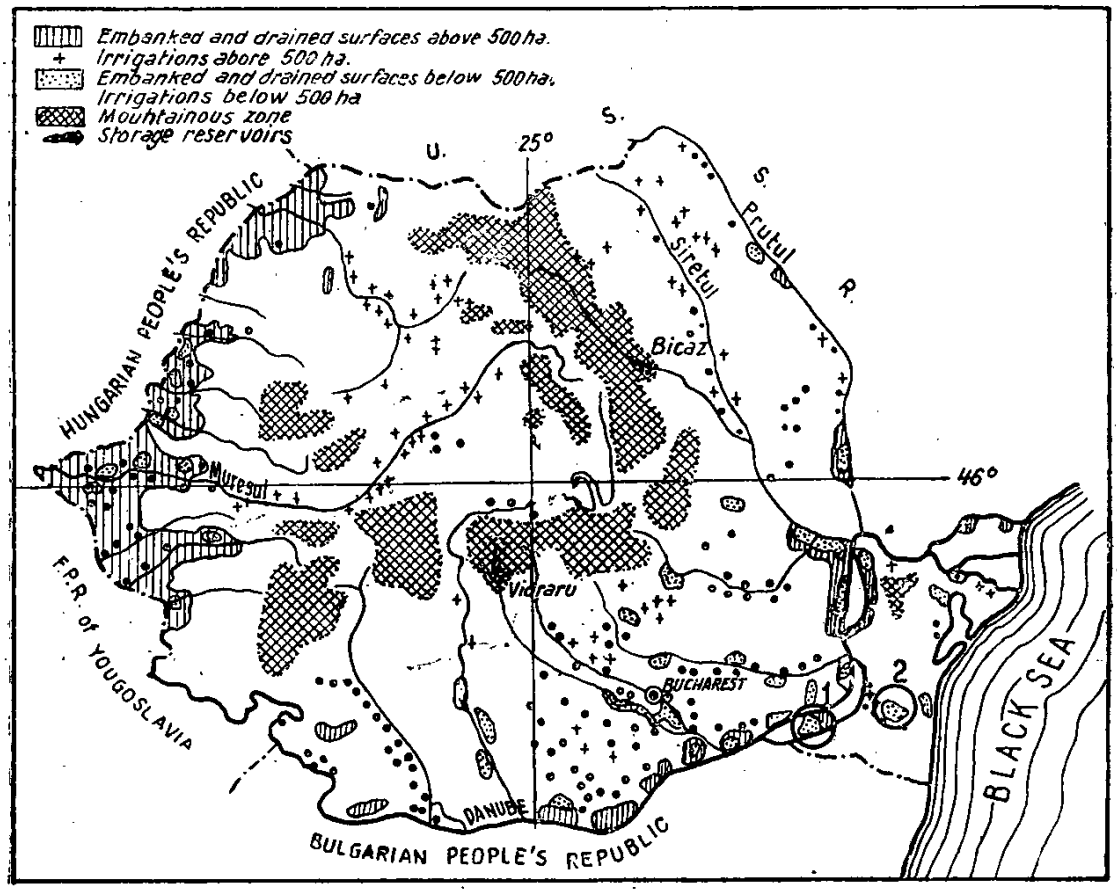

Fig. 2. The zones where reclamation works were executed in the Rumanian People's Republic:

I — The "Borcea de Sus" reclamation system;

II — The "Mircea Vodă" (Carasu) irrigation system.

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in the Rumanian People's Republic. The regions where the works were more extensive are situated in the western part of the country (the Tisa Plain) and in the southern part (Danube Flood Plain, the Rumanian Plain and Dobrudgea Tableland).

The brief data presented in connection with the achievements made by the end of 1962 show that up to the present greater attention was paid to works of flood control and removal of the periodical water excess (embankments, drainages) in order to organize an intensive agriculture.

The irrigation works were developed at a slower rate as during that interval it was necessary to make a number of surveys and experiments specific to this sort of works, on the basis of which irrigations could be greatly extended in the following years. The surveys carried out so far made it possible to know the natural and economic conditions of irrigation development and to draw up plans for the improvement of watercourses, in order to achieve a rational water management.

Within the framework of this development, the main concern was the designing of pumping stations for water disposal (at drainage) and for water supply (irrigation). The technical conception in the design of pumping stations changed in the course of time, alongside of world technique, as follows:

— in the last century the pumping stations for water disposal used especially for drainage in the Western Plain were driven by steam engines (Fig. 3);

— for more recent drainage works high capacity pumping stations with modern equipment driven by electric motors were provided (Fig. 4);

— nowadays, pumping stations are intended to serve both drainage (disposal) and irrigation (supply) based on the reversibility principle, especially at the embanked enclosures in the Danube Flood Plain; the present tendency regarding such pumping stations is to renounce the expensive buildings of the stations and to employ pumps located

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Fig. 3. Steam driven pumping station for drainage at Zerind (Western Plain) (Built in 1901 for Q = 2 m³/sec).

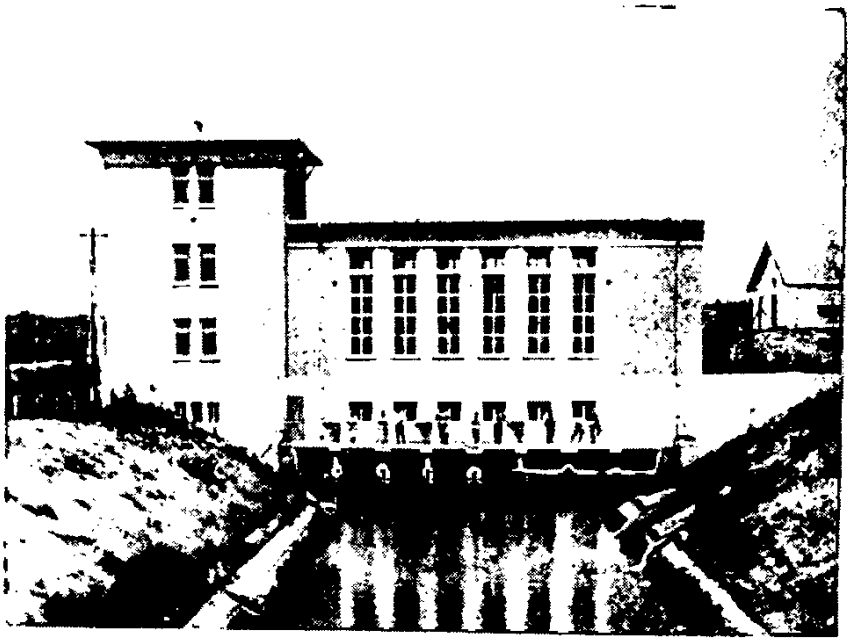

Fig. 4. Pumping station for the drainage of the Luciu — Giurgeni (Danube Flood Plain) embanked zone driven by electromotors (Built in 1958 for Q = 6 m³/sec).

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in caissons and driven by sealed electromotors situated at the ground level (Fig. 5);

— floating pumping stations are more and more used in irrigation when the water is supplied by rivers with great level variations and unfavourable conditions for fixed shore structures (Fig. 6).

The people's democratic regime shows a great concern for the continuous development of reclamation on the basis of a concrete long term plan, included in the provisions of the development schemes for water economy.

Conforming to the long term provisions, embankment and drainage works will be carried out in an area reaching a total of 1 million ha by 1965 and in the following 10—15 years the development of the remaining areas requiring such reclamation works will be completed.

As regards irrigation, in the first (immediate) stage, development works will be performed on about 1 million ha in the arid plain region in the south, and afterwards, in a second stage, this area will increase to about 2 million ha. Most of the area will be supplied by the Danube as well as by the larger inland rivers. The flow of the latter will be regulated by means of storage works of which the most important are mentioned :

— the Bicaz reservoir (1,200 million m^3) in the Siret river basin which is already in operation and supplies a hydro-electric plant with an installed power of 210,000 kW and also ensures the water supply for irrigating 300,000 ha in the northeastern part of the Rumanian Plain (Fig. 7);

— the Vidraru reservoir (320 million m^3) in the Argesh river basin which is under construction will ensure in 1963 the driving of a hydro-electric plant with an installed power of 220,000 kW as well as the water supply for the irrigation of an area of 100,000 ha in the central part of the Rumanian Plain.

The following chapters briefly present the reclamation problems, the technical and economic solution as well as the

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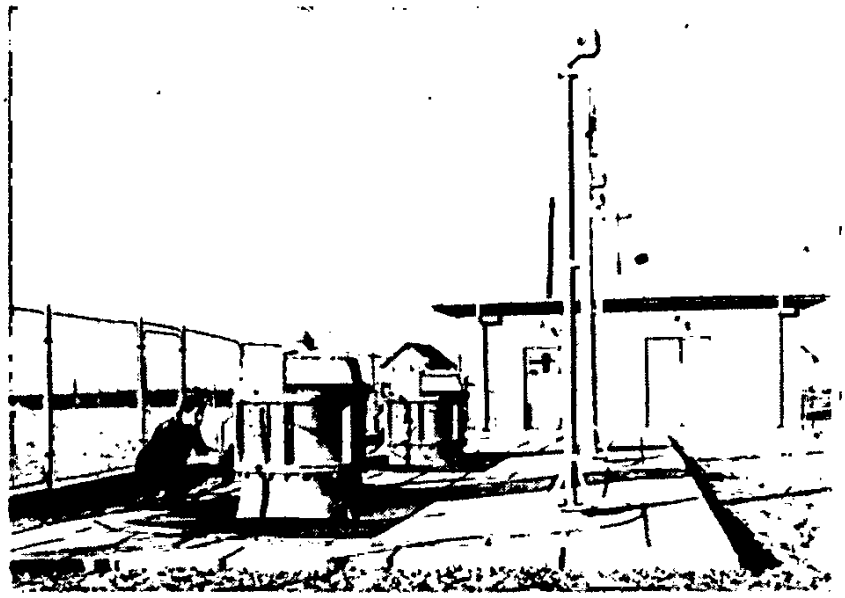

Fig. 5. Irrigation and drainage reversible pumping station in the Călmățui — Gropeni II zone (Danube Flood Plain) driven by sealed electric motors without superstructure (Built in 1960 for Q = 3.6 m³/sec).

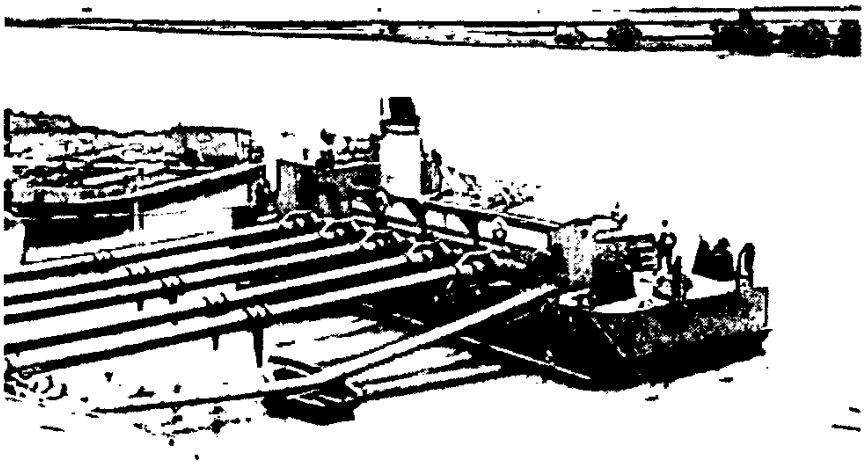

Fig. 6. Floating pumping station for the irrigation of the Călărași terrace (Rumanian Plain) driven by thermic engines (Built in 1957 for Q = 2.4 m³/sec).

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Fig. 7. General view of the Bicaz storage reservoir (storage volume 1,200 million m³; installed capacity 210,000 kW).

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economic results obtained at two different irrigation and drainage systems :

1. The complex of embankment, drainage and irrigation works of the "Borcea de Sus" reclamation system, which represents a typical example as regards the way of solving this sort of reclamation works in the Danube Flood Plain ;
2. The "Mircea Vodă" (Carasu) irrigation system which also represents a typical example for solving the development of irrigation in conditions of macroporous soils (loess) with considerable gradients and sensitive to wettening of the Dobrudgea Tableland.

1. The Complex of Embankment, Drainage and Irrigation Works of the "Borcea de Sus" Reclamation System

The "Borcea de Sus" unit is an island of large proportions situated between the main Danube river bed and the Borcea, one of its arms. The railway between Bucharest and Constantza divides this natural unit into two subunits known as "Borcea de Sus" (Upper Borcea) and "Borcea de Jos" (Lower Borcea).

The "Borcea de Sus" subdivision having an area of 34,000 ha is situated between km 300 and 344 on the Danube (Fig. 2).

Until 1949, this territory was in natural flooding regime a fact which prevented any safe and rational agricultural operation. The major part of the land was covered by swamps and ponds resulting from floods, overrun by a strongly developed lacustrine vegetation. The only zones where an agricultural exploitation was attempted were the higher tops of a bank ridge near the banks with limited areas where wheat and maize were grown at the risk of the crops being yearly destroyed by floods.

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After the withdrawal of flood water, the small areas not yet overrun by reed and mace reed were also used as natural pastures.

Beginning with 1949, a number of surveys and field investigations were made and plans drawn up providing the flood control of the "Borcea de Sus" unit by means of an unsubmersible belt embankment, as well as the improvement of the inner land by a complex of improvements (drainage, irrigation and removal of reeds, etc) in view of obtaining a rational and intensive cultivation of the land.

The main reclamation works carried out in this unit, their technical solution and the economic results are briefly presented below.

a. *Embankment*

In 1949, the studies and the designs for the embankment of the whole "Borcea de Sus" subdivision were finished. The design provided for the building of an unsubmersible earth belt embankment with grass covered slopes and with the downstream ends incorporated into the filling of the Bucharest—Constantza railway line. The whole protected area is to be divided into three compartments by two cross dikes (Fig. 8).

The measures taken for dividing this area were determined by the specific conditions of this unit entirely surrounded by water being thus exposed to the danger of a possible breaking down of the embankment. In this case, the flood may be localized only in one compartment thus saving the crops and other goods situated in the other compartments. The division into compartments enables the building of the embankment to be carried out in stages covering several years.

Out of the total area of 34,000 ha of this subdivision it was decided that 28,240 ha should be damned in, being divided into the three compartments as follows :

— First	9,040 ha
— Second	7,500 ha
— Third	11,700 ha
	28,240 ha

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The remaining 5,760 ha were left outside the embankment between the embankment and the riverside because the surrounding embankment is at a distance of about 200—400 m from the

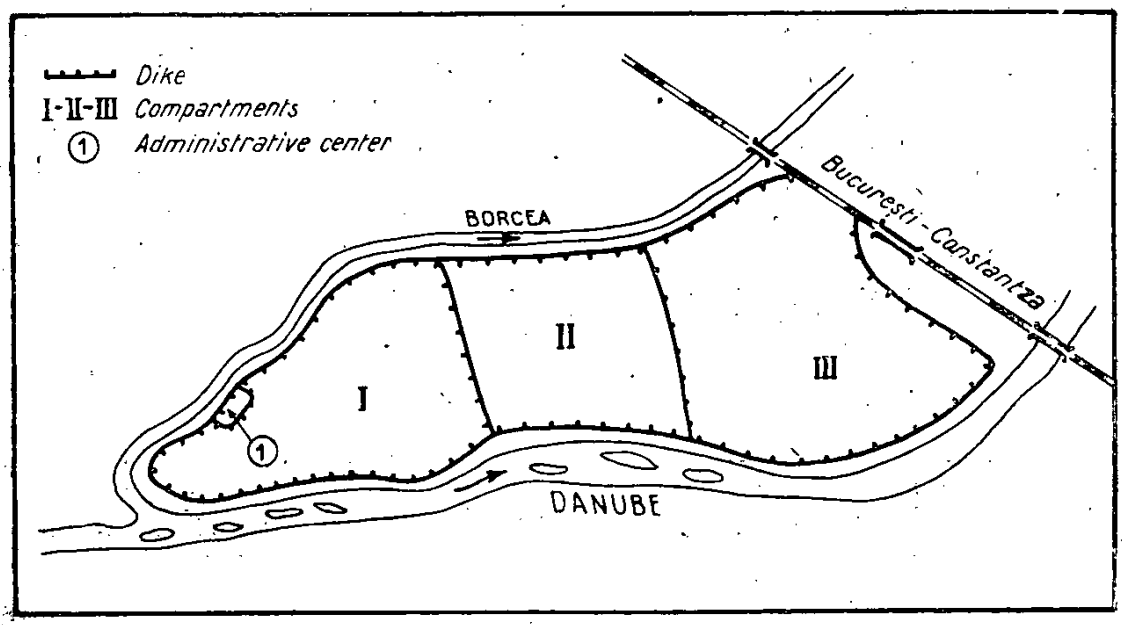

Fig. 8. Embankment works of the subunit "Borcea de Sus" (compartimentation).

normal bed in order to enable the river in spate to flow without overraising the water level or turbulent flow.

The cross—section commonly used in the Rumanian Danube sector was adopted for the surrounding embankment with the following dimensioning elements (Fig. 9):

— width of the crest	5.50 m
— security height above maximum waters	1.50 m
— outer slope	1/3
— inland slope	1/1.5

The earth used for the construction of embankments has a medium sandy-clay texture.

In order that the infiltration line should remain within the body of the embankment, a bench was provided in the interior

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with the crest situated at 1.00 m below the level of the maximum waters, having the following design elements :

— width of the crest	4.00 m
— slope	1/1.5

The crest of the embankment has an outward slope of about 9 per cent for the discharge of rainwater.

The level used in computations was the highest one recorded in 1897, which corresponds to a level assurance of about 1 per cent.

The embankment of the first compartment was achieved in 1950—1953 so that by the end of 1953 this compartment was completely protected by an unsubmersible belt embankment, 42 km long, with a total volume of 3 mil. m³ (330 m³/ha). Eight cabins (one for every 5 km of embankment) and a 18 km telephone line connected to the respective administrative center were set up for the watching and maintenace of the embankment.

For the cross embankment which separated the compartments, a section differing from that of the belt embankment was adopted, having the following dimensions :

— width of the crest	5.00 m
— gradient of both slopes	1/3

Inside compartment I, as an additional safety measure, the local embankment of a farm center consisting of a number of buildings requiring a volume of earthworks of about 100,000 m³ was executed.

The embanking of the second and third compartments was conditioned by previous laboratory model tests to check the

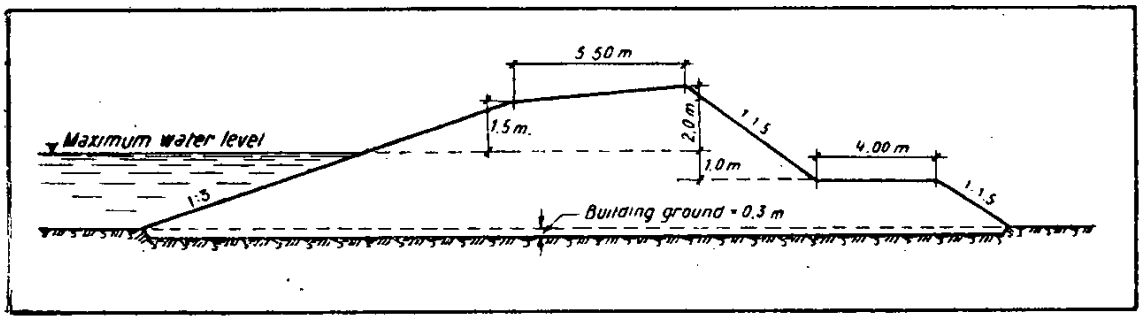

Fig. 9. Cross-section through the belt embankment of the Compartment I — Borcea de Sus.

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degree in which the piers of the downstream railway bridges would be affected as a result of the narrowing of the flow section at high waters.

Before the model tests for the embankment of compartments II and III were finished smaller unsubmersible earth embankments were built to protect the enclosed land from the annual lesser floods of the Danube corresponding to an assurance of about 20 per cent (8—8.5 hydrogrades). The final conclusions drawn by the Hydrotechnical Research Institute were favourable to the construction of unsubmersible embankments around compartments II and III which was begun in 1962 and is to be completed in the course of 1963.

The complete flood control of the first compartment and the partial control of compartments II and III by temporary works facilitated the systematic agricultural exploitation of the embanked territories. With that end in view, several measures for the removal of reeds and clearing the ground and the corresponding irrigation and drainage works were accomplished in the first compartment. New State Farms which have already reached a high level of development were set up on these lands. Among these, the "Pietroiu" State Farm occupying the first compartment, yielded record crops being one of the frontranking farms in the country (Fig. 10).

Fig. 10. Irrigation maize crop at the "Pietroiu" State Farm, Compartment I—Borcea de Sus.

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b. *Drainage works*

Up to the present, the draining of the land was solved only in the first compartment, this being the only one entirely protected by the embankment.

During the first stage (1954) less complete draining was assured by setting up a rather loose network of canals along the lines of the small existing gullies which ensure the flow of internal waters into a main collector. The waters were returned to the Danube in the south of the enclosure either by gravitation (through a reinforced concrete pipe provided with a sluice gate built in the body of the embankment) at low levels of the river, or by means of a temporary pumping station with a delivery of 1.5 m^3/sec at high and medium levels.

The light draining enabled the water disposal of the interior ponds and of the rainwater collected in depressions allowing the land in the enclosure to be gradually put under the plough as ground clearing progressed.

At the same time, a network of wells for hydrogeological observations was organized with a view to a systematic recording of the evolution of the water table level after embanking in order to know as accurately as possible how much the drainage should be extended.

Later (1959), on the basis of field observations and especially after the development of irrigations the extension and deepening of the drainage network was undertaken (Fig. 11).

At present, the drainage of the first compartment is well ensured by a network of open ditches with a total length of 44 km (1 km of ditches for about 205 ha) with a depth varying between 1.5—3 m. The execution of the drainage network required a total volume of 312,000 m^3 with a specific index of about 35 m^3/ha.

For the disposal into the Danube of waters drained from the first compartment a permanent pumping station (Fig. 12) was constructed by which a mechanical uplift of a 3.100 m^3/sec

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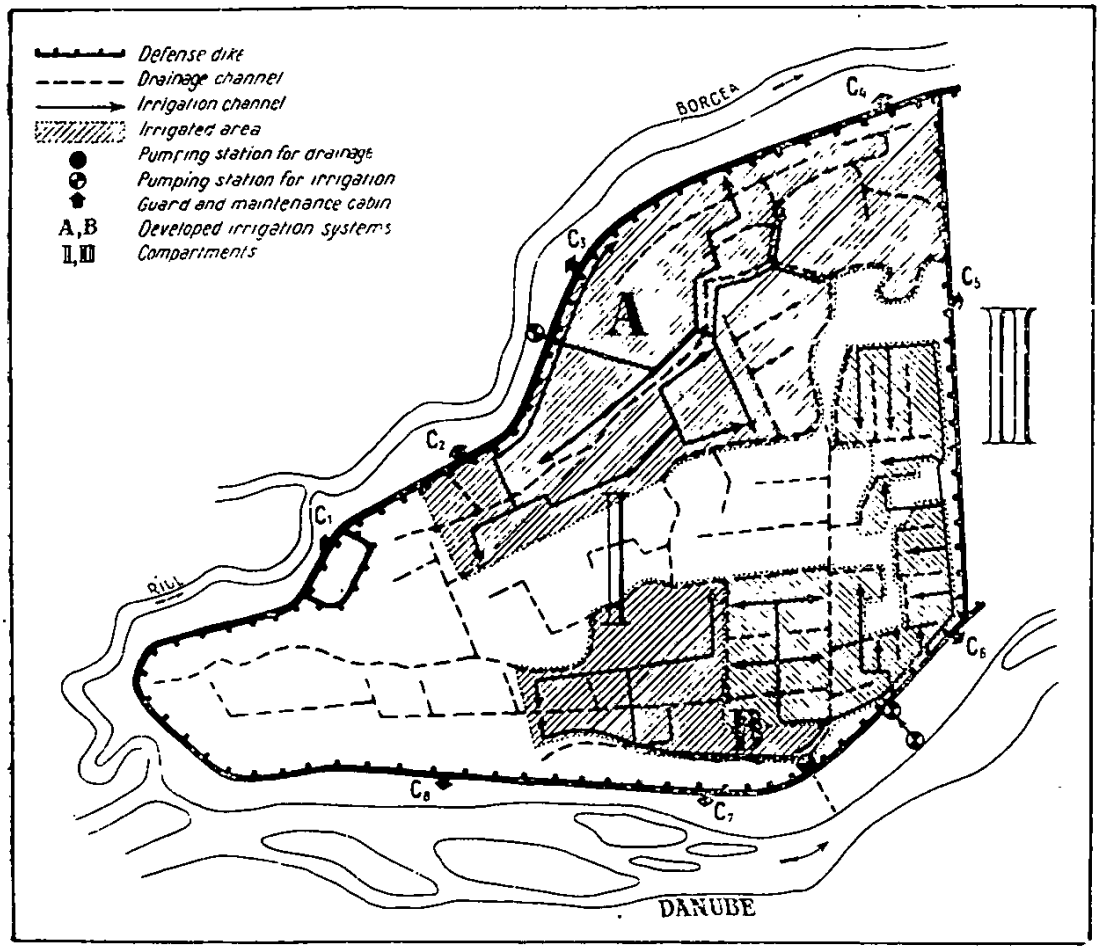

Fig. 11. Complex of irrigation and drainage works (embankment, drainage, irrigation) of Compartment I — Borcea de Sus.

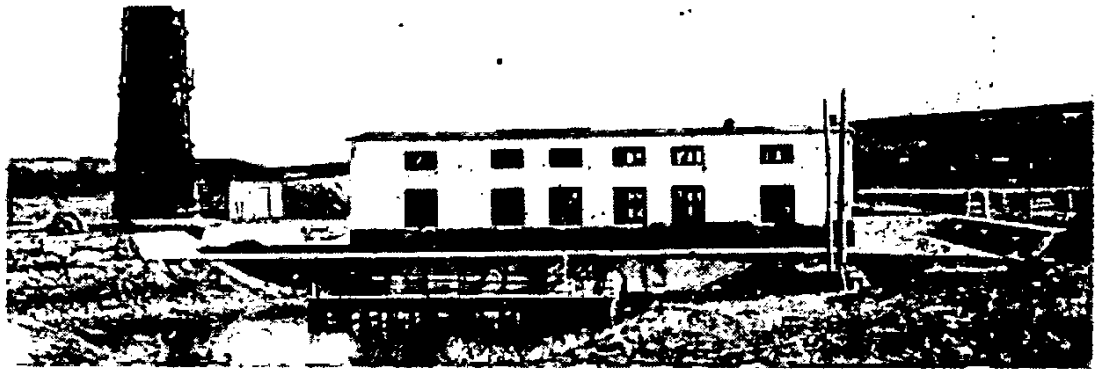

Fig. 12. Permanent pumping station for the drainage of Compartment I — Borcea de Sus (Built in 1960 for Q = 3.1 m³/sec).

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discharge is ensured (0.35 l/sec and ha). The execution of the suction basin at the pumping station raised very difficult problems as due to the design level of the floor a layer of fine quick-

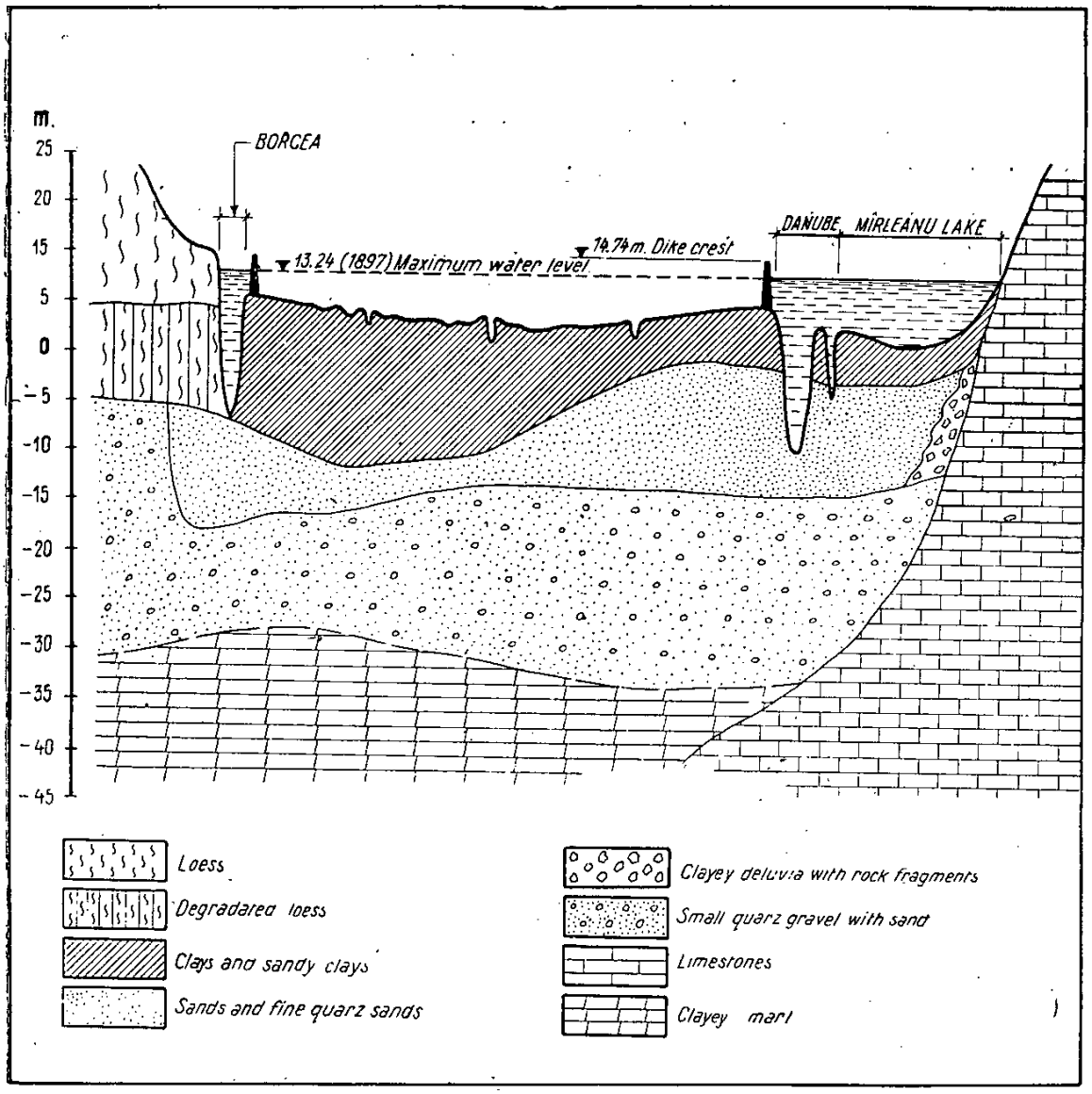

Fig. 13. Geotechnical cross-section through Compartment I — Borcea de Sus.

sand situated at 1.5—2.00 m from the ground surface was reached as shown in the geological cross-sections of the first compartment (Fig. 13). In order to carry out the cuttings, it was necessary to use a set of well points disposed in several lifts as excavation progressed.

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By executing these draining works more and more intensive cultivation of the enclosed land was made possible with parallel extension of irrigation.

c. *Developments for irrigations*

At the same time with the draining works, the developments for irrigations also took place in the first compartment.

The irrigations extended on the basis of a development scheme of the enclosure which provided for the extension of irrigation on a total surface of 5,820 ha consisting of three systems, each with its own supply unit (pumping stations).

On the whole, out of the surface of 5,820 ha planned for irrigations, 3,620 ha were developed for field crops, vegetables and rice up to the end of 1962, and the rest will be developed in the 1963—1964 period (Fig. 14).

The irrigation method employed is by furrows and sprinkling the field crops and vegetables and by submersion for rice. The rough hydromoduluses for dimensioning the canal network

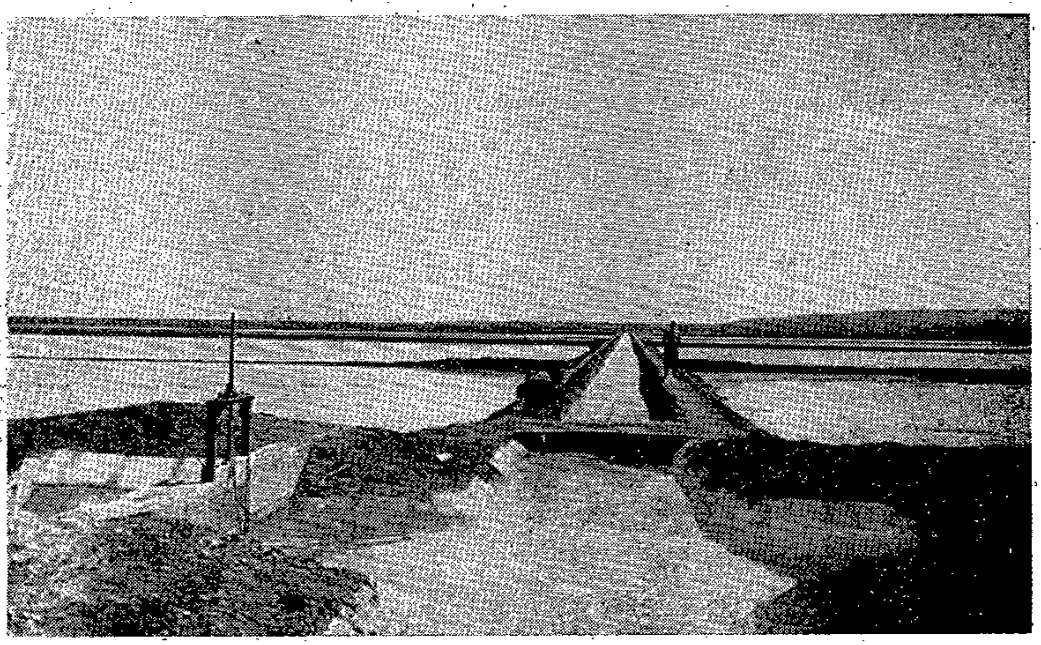

Fig. 14. General view of the development for rice irrigation (submersion) in Compartment I — Borcea de Sus.

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vary between 0.5—0.7 l/sec and ha for field crops and vegetables and between 2.5—3.0 l/sec and ha for rice cultures by rotation.

For the development of these irrigation systems the following earthwork specific indices resulted :

— for furrow irrigation	300 m³/ha
— for irrigation by sprinkling	150 m³/ha
— for irrigation by submersion (rice)	800 m³/ha

Important annual productions are obtained by irrigating the crops. Thus, in 1962 an average production of 8,280 kg grains per ha was obtained from a surface of 610 ha cultivated with maize.

d. *Conclusions on performed reclamation works*

By executing the embanking, draining and irrigation works in the first compartment on the "Borcea de Sus" subunit, an area of 9,040 ha was included in the agricultural circuit, a fact which enabled the setting up of a great State Farm named "Pietroiu".

In the first years after the execution of embanking and draining works, the respective lands completely changed their aspect. The former surfaces of reed plots and ponds are now fertile fields.

Great productions are now obtained under irrigated and non-irrigated regime, by carrying out the adequate reclamation and agrotechnical works.

The productions currently obtained under non-irrigated regime are : 2,000—2,500 kg/ha winter wheat and 3,000—5,000 kg/ha grain maize.

Under irrigated regime, yields two or three times greater can be obtained :

— winter wheat	4,000— 5,000 kg/ha
— maize (grains)	8,000—10,000 kg/ha
— sugar beet	60,000 kg/ha
— rice	4,000— 5,000 kg/ha

The economic results obtained by applying the complex system of reclamation works together with the adequate farming

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methods in the first compartment of the "Borcea de Sus" subunit is a good example of the important contribution of such works for the development of fertile fields in the Danube Flood Plain.

At present, the extension of the reclamation works both in the other two adjacent compartments and in other natural regions of the Danube flood plain is accomplished at a steady rate.

The "Mircea Vodă" (Carasu) Irrigation System Executed on Loess

Within the irrigation extension plan, an irrigated territory of about 2 million hectares is foreseen. Of this surface, more than one half is located in loess zones.

In order to ensure the proper operation of the irrigation systems which will be created in the loess zones and to find the best methods of preventing or reducing damages caused by loess moistening, it was decided to develop experimentally the irrigation system of "Mircea Vodă" where the necessary observations and investigations could be made at the same time as exploitation.

The "Mircea Vodă" irrigation system is located in the south-eastern part of the country in Dobrudgea (Fig. 2), between the Danube and the Black Sea (Fig. 15).

In this zone, climate is characterized by frequent drought periods lasting for 80—110 days during dry years. The multi-annual average rainfall is of 369 mm.

The area of 4,000 ha developed for irrigation is situated on the slopes of the Carasu Valley being characterized by gradients generally of 3—5 per cent and locally exceeding 5 per cent.

Slopes of over 8 per cent gradient were excluded from irrigation.

Generally, irrigation is applied to field crops (maize, corn, sugar beet, lucerne) and to fruit trees (especially peach trees).

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Water supply of the irrigation system is effected from the main canal executed in the Carasu Valley which receives water pumped from the Danube (Fig. 16).

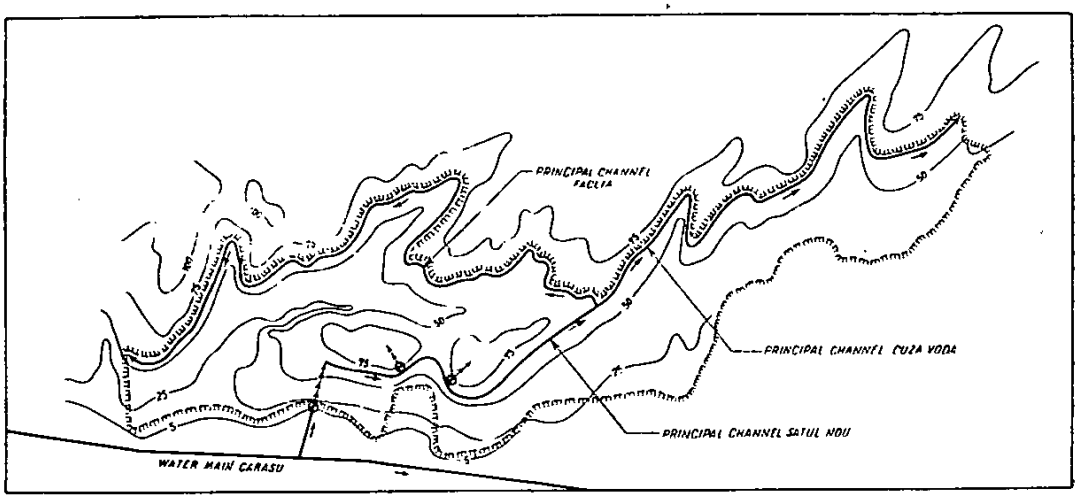

Fig. 15. The "Mircea Vodă" (Carasu) irrigation system.

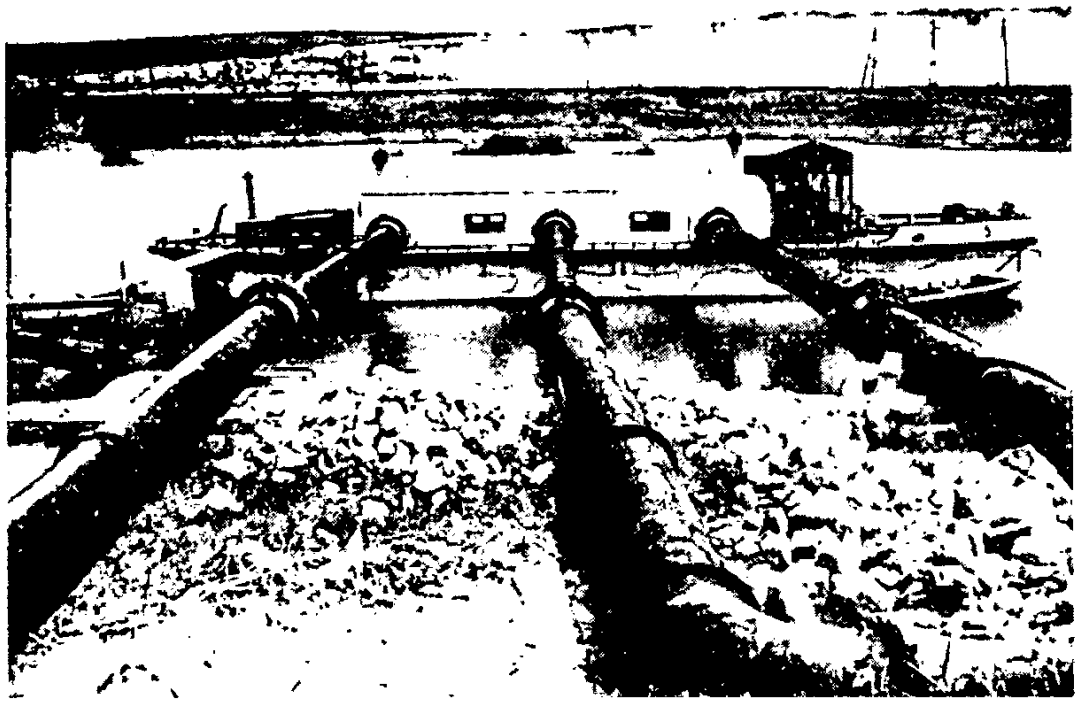

Fig. 16. Floating pumping station of the magistral canal of the Carasu Valley.

Water is pumped from this canal at a height of 60 m with a discharge of 2.4 m^3/sec (Fig. 17, 18 and 19). From the discharge

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Fig. 17. Retaining valve on discharge pipes of the "Mircea Vodă" (Carasu) irrigation system.

Fig. 18. Discharge pipes of the pumping station in the "Mircea Vodă" (Carasu) irrigation system.

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Fig. 19. Discharge basin of the pumping station in the "Mircea Vodă" (Carasu) irrigation system.

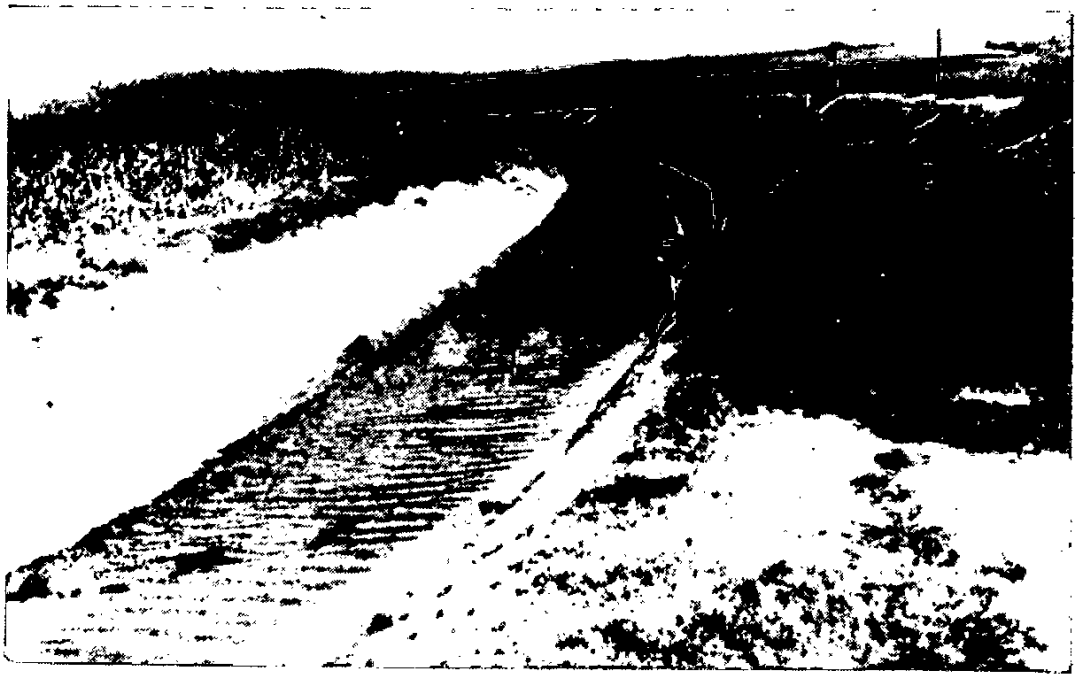

Fig. 20. The „Satu Nou" main canal in the "Mircea Vodă" (Carasu) irrigation system.

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basin, water is conducted approximately along the + 65 m contour line through three canals :

— the main canal "Satu Nou", 9.4 km long, dimensioned for 2.4 m³/sec with extension possibilities in the future to 17 m³/sec for the upper pumping levels (+ 80 m and + 110 m) (Fig. 20);

— the main canal "Făclia", 19 km long and the main canal "Cuza Vodă", 10 km long, both dimensioned for about 1.00 m³/sec.

The main canals were executed in cutting, in general with the water level equal to the ground level, the safety height of canals above the water level being achieved by filling.

The main canals were given in exploitation without waterproofing or previous treatment of loess.

The hydrotechnical structures were executed after compacting the foundation ground on which a loess-cement mixture layer with a dosage of 50—75 kgs cement per m³ loess was laid. Stabilized soil has a thickness of 0.5 — 2.0 m depending on the importance of the hydrotechnical structure.

The secondary canals, orientated along the line of greatest slope were coated with stone packing of local origin, placed on a concrete bed (Fig. 21).

The sprinkling method is applied on about 60 per cent of the irrigated surface and furrow irrigation on the remaining 40 per cent. Taking into account local conditions (steep gradients and wind) the possibility of modifying these percentages and the irrigation methods was foreseen.

★

The areas of the Rumanian People's Republic mostly interested in irrigation are situated in the loess zone and for this reason particular attention was paid to the study of the behaviour of canals and hydrotechnical structures in the "Mircea Vodă" system.

Therefore, field and laboratory studies were made on the basis of borings executed before designing, studies which continued parallel with the exploitation works by effecting new borings

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and laboratory investigations and especially by observing the behaviour of the works in this irrigation system and by various

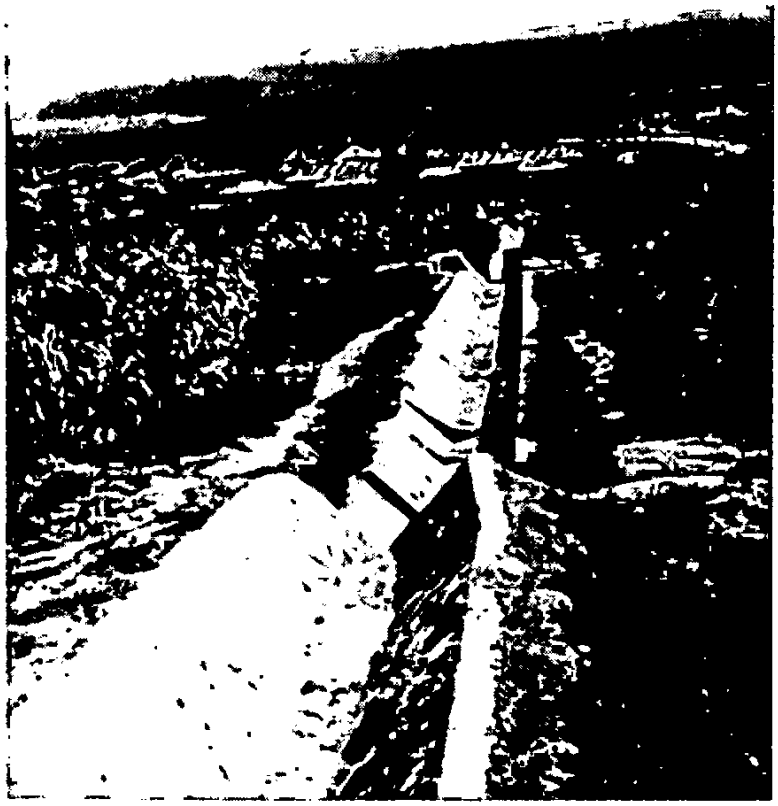

Fig. 21. Secondary canal on the line of the greatest slope coated with stone pavements in the "Mircea Vodă" (Carasu) irrigation system.

experiments made on limited areas situated inside the irrigation system.

It resulted from the preliminary studies that under the topsoil 0.5—0.6 m thick follows the loess layer 12—20 m thick, situated in most cases on a clayey loamy system beneath which lies the limestone layer. In certain borings, a layer of sand and gravel was found beneath the loess.

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There is no continuous water bearing stratum under the loess, as it occurs only at certain points.

Before the irrigation system was executed, the natural loess moisture was of 9—10 per cent in the upper part, increasing to 13—14 per cent at about 10 m depth and 15—17 per cent towards the bottom.

The particle size distribution is relatively homogeneous, the silt content (with a diameter of 5 to 50 microns) exceeding 60 per cent.

Pore volume presents great variations, generally decreasing from 48 to 50 per cent at the surface and to 40 per cent towards the bottom.

The additional settlement by moistening determined in the oedometer under 3 kg/cm^2 is of 3.3—7.8 per cent decreasing in depth.

Permeability determined in the laboratory is of 10^{-4} cm/sec at the surface and only 10^{-5} to 10^{-6} cm/sec in depth.

The irrigation system was put into operation during 1959.

Although certain important settlements took place, the operation of the irrigation system could be ensured in parallel with the remedying of the damages incurred.

Against the total length of main canals of about 40 km, where water circulated permanently 6—8 months a year, zones with important settlings occured at about 15 points in the form of elliptic depressions, with the main axis directed along the canal, having the length of 120—200 m and extending crosswise for about 30—60 m. The depth in the center of the settling zone was of 0.8—1.8 m.

Important settlings alternate at small distances with other unaffected zones (Fig. 22, 23).

Settlements were accompanied by fissures several tens of centimeters wide and 5—8 m deep, including the crumbling of the massif between fissures (Fig. 24, 25).

In the remaining canals there appeared settlements of 0.3 -- 0.5 m, accompanied by narrow longitudinal fissures or

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Fig. 22. Settling on the irrigation canals.

Fig. 23. Settling on the irrigation canals.

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settlements up to 0.2 m with invisible effects, nevertheless considerable canal portions remained without fissures or settlings.

On the 4,000 ha irrigated area where water arrives periodically more important settlements occured only in two places.

Fig. 24. Fissure in the irrigated loessoid soil.

On the secondary canals, where water flows periodically settlements occured only in the zones around the branching of secondary canals from the principal ones and only in the case when a settlement on the principal canal occured in the branching zone.

In order to ensure the flow of water in canals in the period of settlings, the maintenance teams executed small dikes on the downward side of the canal, in the zones where due to settle-

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ment, water rose above the canal section overflowing onto the banks and running down the slopes (Fig. 22, 23). In this way interruptions in the system operation due to the settlements produced on canals were unimportant.

Losses through infiltrations measured by infiltrometers as well as statically on certain previously isolated sections of the principal canals were of 10 — 20 cm water column per day. At the first flooding of the canal, losses were five times greater and decreased to a steady value in 1.5—2 months by achieving a natural colmatation process.

Fig 25. Fissure in the irrigated loessoid soil.

Important losses were also observed during the following years at the first filling of the canal with water, but these were smaller than at the original filling.

Under the influence of infiltrations, the loess moisture grows as a strip along the canal, being bell shaped in cross-sections with a fringed border line, below the canal moisture exceeds 21 to 24 per cent (Fig. 26).

The width of the bell is of about 20 m on each side of the canal when loess has at its base a waterproof layer and is only of 7—8 meters when loess is situated on a sand and gravel layer.

After irrigation, in the degradated and unrepaired zones, moisture content in loess grew markedly and became wider, the fissures being a source of water penetration in depth.

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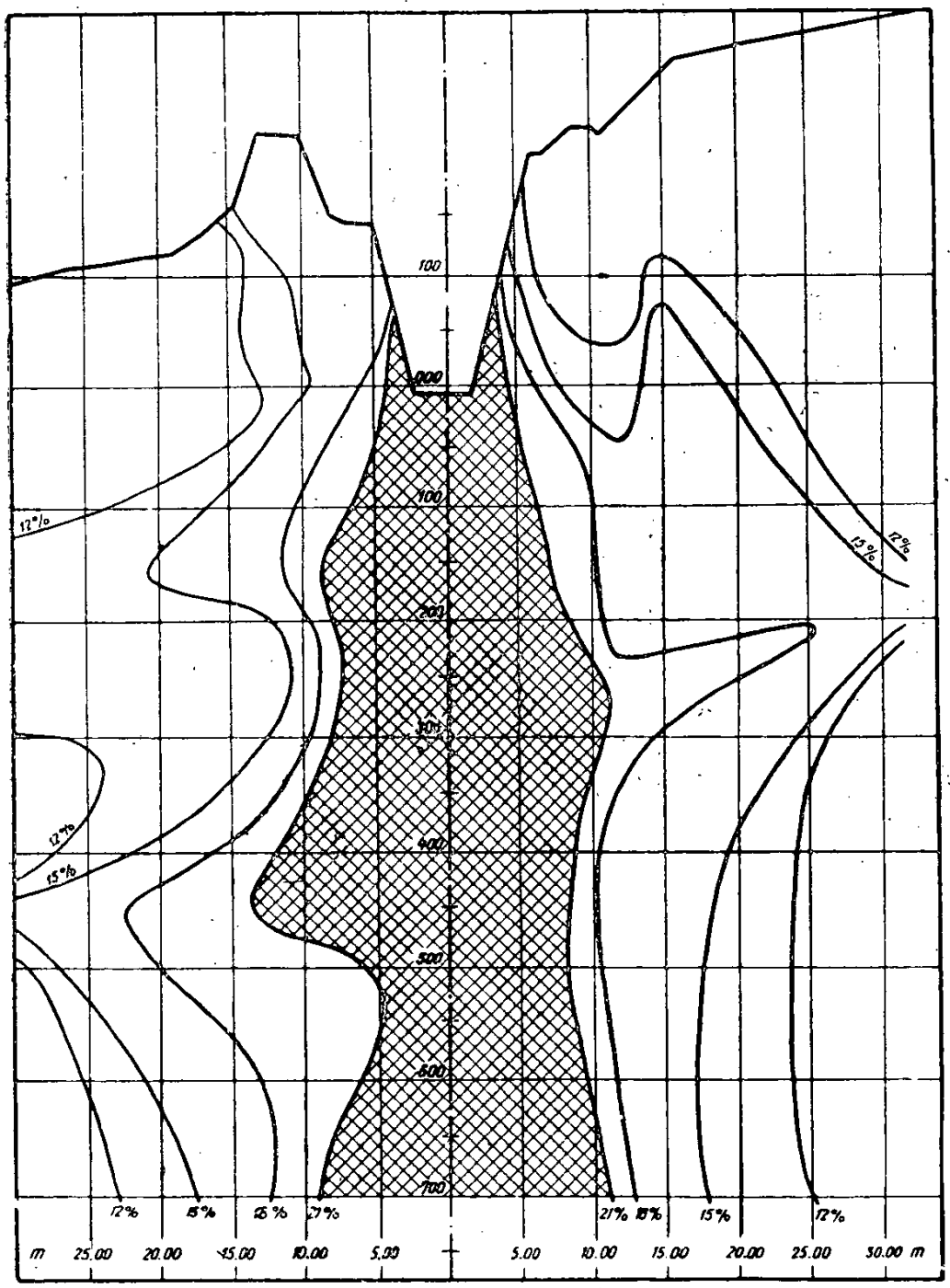

Fig. 26. Infiltration of water under the irrigation canals in a loessoid soil.

It was found that the best measures to take for remedying settlings were those of remaking the canal section on the same line with well compacted loess filling; these kind of repairs stopped

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the settling process and decreased the moisture in the zone underlying the canal.

The experimental repairs, by deviating the canal line, or those achieved during operation by maintaining a pond in the collapsed zone limited on the downward side by a small dike, did not yield good results; in the first case, the settling process recurred and in the second it extended in area.

It was generally found that the most important settlings occured in the first 6—8 months of operation of the canals and by the third year of operation the settling process was reduced. The settling process at the same point lasted in certain cases more than one year.

Several interesting findings refer to the causes which generated settlements, or which prevented their occurence.

Thus, in general, settlements were not produced in loesses less than 9 m thick; important settlements occured in the zones where the loess thickness exceeded 15 m, but not in every case.

As an example, a length exceeding 1 km on the "Cuza Vodă" canal is given, where loess thickness exceeds 20 m and where no settlements occured; the loess in this zone lies on a sand layer which drains the infiltrated water, so that the moistened zone in the loess remained reduced.

Important damages occured in nearly all the cases where there are tree strips which contribute to the maintenance of a high moisture content and favour infiltrations; one of the two cases of large settlements which occured on the irrigated area is situated in a lucerne field which like the tree strips, favours infiltration by its deep roots.

In the zones without protective tree strips, a reduction of the infiltration bell, consequently a limitation of the moistened volume was recorded in summer.

This limitation of the bell width is very important when taking into consideration that in the moment of loess failure the zone with a high moisture was of the order of 20—30 m on each side of the canal; with smaller widths, settling did not occur.

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The widening of the water surface in the settled zone, hence the overflow of water from the canal section, extends and accelerated the settling of loess; it is therefore recommended to restore the section of the canal on both sides as soon as settling occurs in order to avoid flooding of the fissures and thus the deep penetration of the water.

The chemical composition of loess in the zones where important settlings occured is variable, in the sense that in these zones loess was richer in soluble salts before settling. In the zones liable to settling, among the clayey minerals the predominant one is the montmorillonite, a very active clayey mineral which in contact with water greatly increases its volume contributing to the disturbance of the loess structure.

In the undamaged zones kaolinit is predominant.

The hydrotechnical structures and small bridges executed on a loess-cement foundation placed after compaction, were very resistent to settling and were not damaged. It is worth mentioning the case of a highway bridge which was founded on compacted loess and on a layer of loess-cement mixture, 2.00 m thick which underwent a settlement of about 0.8 m without damage. The cone quarters and stone-paved jointings which were not placed on loess concrete, settled much more than the bridge.

It must be shown in conclusion that the investigations and studies carried out have established certain causes which produce or prevent settling in loess and will help in the designing of the future irrigations on loess. At the same time it resulted that damages on loess were not so important as to hinder the extension of irrigations in these zones.

It was found that the operation of canals without coatings or special treatments, with the subsequent remedying of degradations, is more economical than the coating or heavy compaction of canals aiming to reduce infiltration and the danger of settling in as much as degradations occur in limited zones and are due to additional causes, some of which were mentioned above.

The studies will continue in order to obtain more information concerning loess settlements.

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